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Phytoplankton composition in Pacific white shrimp ponds, Phetchaburi Province, upper Gulf of Thailand

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Abstract Phytoplankton composition in Pacific white shrimp ponds was reported. The results can be used as a guideline for effective management planning of the shrimp farms. The phytoplankton composition was studied at shrimp farm in Phetchaburi Province, upper Gulf of Thailand. A total of 21 species of phytoplankton were recorded. The blue-green algae group was a dominant in terms of the number of species (7 species), and green algae group was a dominant in quantity (90.20% of all phytoplankton), followed by euglenoid (3.70%) and blue-green algae (3.21%). *Scenedesmus* sp. was the most quantity of all genera in the ponds of this study, with a total density of 147,389.95 cells/liter or 88.73% of the total phytoplankton. In the culture periods, the density of phytoplankton tended to increase along the culture period. The total phytoplankton density had a high level of positive correlation ($r=0.994$) with statistical significance ($p<0.05$) with orthophosphate. Moreover, green algae were also highly related ($r=0.990$) with orthophosphate ($p<0.05$). Also, the relationship between the ecological index and water quality parameters showed that all ecological index had no statistically significant relationship ($p>0.05$).

Keywords: Pacific white shrimp, Phytoplankton, Phetchaburi.

Introduction

Demand for Pacific white shrimp production continuously increases every year, resulting in Pacific white shrimp farmers having to shorten the time to culture and increasing production continuously, such as high stocking density, increasing food intake and development of feed formulas. These have a continuous impact on the balance of the pond's ecological system, which is often followed by environmental problems in the ponds (Páez-Osuna, 2001). Mainly, the problem of increasing the amount of phytoplankton affects the

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productivity of aquatic animals. In general, changes in the amount of phytoplankton in aquaculture ponds relates to changing some of nutrients in the water, which was in most cases, the nutrients in the ponds tend to increase accumulate during the culture period due to the accumulation of waste, both food waste and excretion of aquatic animals (Alonso-Rodríguez and Páez-Osuna, 2003). The main nutrients affecting the change of phytoplankton in aquaculture ponds was nitrogen and phosphorus in the water, because these elements were important factors since the phytoplankton used them to grow and multiply rapidly (Burford, 2008). Environmental factors in aquaculture ponds were significant for aquatic animal products. Especially the factors of phytoplankton and water quality in the ponds, both were interrelated. If the farmer did not know how to control the factors or their effective controlling was not good enough, it would directly affect the productivity of the aquaculture ponds such as an increase in the amount of phytoplankton that was too high, so it could affect the lack of oxygen at night (Dampin, 2011). The problem of quantity and population structure changes of phytoplankton in the ponds, if it was not suitably managed, it would significantly affect the production in the pond (Case ´*et al*., 2008).

Now, Pacific white shrimp farming in Thailand has commercially developed the pattern and method of culture in order to respond to the needs of consumers. The farmers have increased stocking density and decreased farming periods more than in the past in the high accumulation of nutrients in the pond system. Moreover, it affects the changes in the quantity and population structure of the phytoplankton. The objective of this study is to evaluate the changes in the phytoplankton population in the present commercial shrimp pond and the factors related to the phytoplankton population change. Furthermore, the knowledge acquired can be easily applied to the guidelines in appropriately and efficiently managing the shrimp pond.

Materials and methods

Study area and pond characteristics

Sample collection was get it from shrimp farm in Ban Lam District, Phetchaburi Province, upper Gulf of Thailand. Samples were collected in 2 ponds and 1 crop per pond in August to November 2019 (Table 1). The most of ponds were small, covering areas of 0.16 hectare. The ponds had 4 aerators in each pond. The culture period was covered in three months for each crop.

Table 1. Average culture pattern and growth performance of Pacific Pacific white shrimp fram

Culture pattern and growth performance	Pond No.	
	1	2
Pacific white shrimp (average per crop)		
- Pond size (hectare)	0.16	0.16
- Pond depth (m)	1.5	1.5
- Stocking density (shrimps/ha)	625,000	625,000
- Shrimp weight at beginning crop (g)	200	200
- Total feed (kg/pond/crop)	1,415.00	1,000.00
- Total shrimp product (kg/pond)	536	360
- Feed conversion ratio	2.64	2.78

Water-quality sampling and analysis

The study of the 10 water quality parameters was focused on the change to the population of phytoplankton in the ponds (Table 1) by collecting water samples at 30 centimeters dept from the surface water. Water samples were collectted in a 1000 milliliter container, kept in a freezer at 4 °C and took to the laboratory for analysis of water quality. Water-quality samples were collected at two ponds in the farm every 2 weeks (8 times per crop) for analysis of environmental condition changes. Sampling was replicated at three sites per pond. All water quality measurements were conducted according to APHA, AWWA, and WEF (2012); standard methods for examination of water and wastewater.

Total phytoplankton estimation

Phytoplankton samples were collected by filtering 20 liters of water through 20 micrometers plankton net. Then, these samples were fixed with 4 % formalin for analysis at the field. Samples were collected in the same location as the water quality samples. Plankton samples were analyzed under the microscope, and identified them with relevant phytoplankton taxonomy documents. Moreover, change would be classified in the taxonomic group and analyzed a phytoplankton density in cells per liter.

Statistical analysis

Water-quality data were analyzed using descriptive statistics. Furthermore, One-way ANOVA analysis was used to compare the differences between various factors such as water quality, phytoplankton density, and the ecological index, if the data were normally distributed, it would be analysed by parametric statistic. In the other hand, if the data were not normally distributed, it would be analysed by non parametric statistic.

Ecological structure data of phytoplankton including density, diversity index, evenness index, and dominant index were based on Krebs (2001). There were 2 steps to analyze a correlation of phytoplankton populations and the water-quality parameters. First, the tested data was a statistic and distribution condition. Then, if the result indicated a condition that was a normally distribution, it would be analysed by Pearson correlations for the analysis of this relationship. On the other hand, if the result showed the condition that was not a normally distribution, then it would be analysed by the Spearman correlation statistics for this relationship at a 95-percent-confidence level.

Results

Water-quality factors in study areas

Water quality data in culture period was analyzed (Table 2). Results of the water quality in the ponds, it was found that the most of the water quality parameters were within the appropriated standard criteria. Nutrients in phosphorus and nitrogen groups increased between the culture periods. Also, transparency was lower than standard criteria at the end of the crop. It indicated that the amount of waste accumulated in the ponds increased with increasing culture periods. While comparing the water qualities during the culture periods, it was indicated that the water quality of all parameters had a statistically significant difference ($p<0.05$), details of water qualities were shown in Table 2.

Species composition of phytoplankton in the study areas

Results of the species and quantity of phytoplankton in the ponds were collected (Table 3). There were five groups of phytoplankton, namely blue-green algae, green algae, euglenoid, diatoms, and dinoflagellate, a total of 21 species. Blue-green algae (Cyanophyta) were found in 7 species, green algae (Chlorophyta) were found in 5 species, euglenoid (Euglenophyceae) were found in 3 species, diatoms (Baciliariophyceae) were found in 4 species and dinoflagellate were found in 2 species. Green algae showed the highest quantity of all phytoplankton groups. Also, *Scenedesmus* sp. was the most quantity of all genera in the ponds, with a total density of 147,389.95 cells/liter or 88.73% of the total phytoplankton, details of density of phytoplankton population as show in Table 3.

Table 2. Average and standard deviation of water quality factors in each culture period

Water quality parameters	Culture period				p-value	Standard
	Beginning crop	1st month	2nd month	Harvesting period		
Temperature (˚ C)	29.51±0.95	30.18±1.47	31.02±0.45	30.20±0.57	0.001	25-32
Transparency (cm)	57.50±10.61	35.00±7.07	30.00±10.61	26.25±8.84	0.000	30-60
Salinity (ppt)	4.50±0.71	3.00±0.00	3.00±0.00	3.75±0.35	0.000	8-25
Dissolved oxygen (mg/L)	4.45±0.75	5.27±0.04	5.72±0.56	7.69±1.77	0.000	not less than 4
pH	8.54±0.07	8.75±0.10	8.72±0.03	8.60±0.10	0.000	6.5-8.5
Alkalinity (mg/l as Calcium Carbonate)	270.33±10.84	222.00±40.78	241.58±25.57	257.50±3.06	0.002	50-200
Nitrite (mg/L as nitrogen)	0.002±0.001	0.139±0.052	0.597±0.095	0.791±0.100	0.000	not more than 0.4
Nitrate (mg/L as nitrogen)	0.038±0.004	0.118±0.012	0.247±0.018	0.191±0.001	0.000	not more than 4.0
Total ammonia (mg/L as nitrogen)	0.059±0.040	0.181±0.103	0.258±0.127	0.448±0.034	0.001	not more than 0.5
Orthophosphate (mg/L as phosphorus)	0.014±0.001	0.013±0.002	0.021±0.001	0.066±0.040	0.000	not more than 0.2

Remak: Standard values were based on ACFS (2016), Bhatnagar and Devi (2013).

Changes in phytoplankton composition were in the study areas

Comparing the amount of phytoplankton in the study area showed that in the culture periods, the density of phytoplankton tended to increase along the culture period (Tables 4, 5 and Figure 1). The beginning of the crop, diatoms was a dominant group (87.30% of total phytoplankton). During the first month of the crop, blue-green algae, green algae, and euglenoid had the same density (23.11-40.22%), while the diatoms dropped to 9.59%. In the second month, euglenoid was a dominant group (64.53%). Also, during the harvesting period, green algae group increased in density by 95.97% all phytoplankton density. In the overall culture period, green algae group was dominant in quantity (90.20 % of all phytoplankton), followed by euglenoid (3.70%) and blue-green algae (3.21%) in Table 3, details of phytoplankton composition were shown in Table 4-5.

Table 3. Average density of phytoplankton population in study area

Species composition	**Average density of phytoplankton (cells/liter)**				**Total density**	**%***
	Beginning crop	**1st month**	**2nd month**	**Harvesting period**		
Division Cyanophyta						
Class Cyanophyceae						
Aphanocapsa sp.		72.0		1,026.0	1,097.80	0.661
Chroococcus sp.	16.5	18.0	31.5	13.0	78.50	0.047
Cylindrospermopsis sp.			631.3	32.0	662.75	0.399
Merismopedia sp.	10.5	180.0	506.3	510.0	1205.88	0.726
Oscillatoria sp.	18.0	191.0	75.0	840.0	1,123.00	0.676
Raphidiopsis sp.			12.5		12.50	0.008
Spirulina sp.		532.0	575.0	50.0	1,156.50	0.696
Division Chlorophyta						
Class Chlorophyceae						
Coelastrum reticulatum	6.0	310.0	162.5	121.0	598.75	0.360
Pledorina sp.				313.0	312.50	0.188
Scenedesmus sp.	36.0	200.0	530.9	146,624.0	147,389.95	88.733
Tetraedron sp.				23.0	23.00	0.014
unidentified green algae		964.0	193.8	361.0	1,518.25	0.914
Division Chlorophyta						
Class Euglenophyceae						
Euglena spp.	31.5	817.0	4,982.5	219.0	6,049.00	3.642
Lepocinclis spp.			6.2		6.15	0.004
Strombomonas sp.		30.0	36.9	25.0	91.90	0.055
Division Chromophyta						
Class Bacillariophyceae						
Coscinodiscus sp.	24.0		31.3		55.25	0.033
Cyclotella sp.	856.5	54.0	12.5	3430.0	4,352.00	2.620
Navicula spp.	10.5	298.0		46.0	354.10	0.213
Surirella spp.	6.0				6.00	0.004
Division Chromophyta						
Class Dinophyceae						
Ceratium spp.	6.0				6.00	0.004
Peridinium sp.	6.0				6.00	0.004

Remask: %* is percentage of average total phytophaplankton.

Table 4. Changes in phytoplankton composition in study areas

Phytoplankton group	Total density of phytoplankton (cells/L)			
	Beginning crop	**1st month**	**2nd month**	**Harvesting period**
Blue-green algae	45.00 (4.38 %)	991.80 (27.08 %)	1,831.50 (23.52 %)	2,468.63 (1.61 %)
Green algae	42.00 (4.09 %)	1,473.00 (40.22 %)	887.20 (11.39 %)	147,440.25 (95.97 %)
Euglena	31.50 (3.07 %)	846.50 (23.11 %)	5,025.55 (64.53 %)	243.50 (0.16 %)
Diatoms	897.00 (87.30 %)	351.10 (9.59 %)	43.75 (0.56 %)	3,475.50 (2.26 %)
Dinoflagellate	12.00 (1.17 %)	0.00 (0.00 %)	0.00 (0.00 %)	0.00 (0.00 %)
Total density	1,027.50	3,662.40	7,788.00	153,627.88

Remark: The percentage in parentheses was a comparison of phytoplankton composition in each culture period.

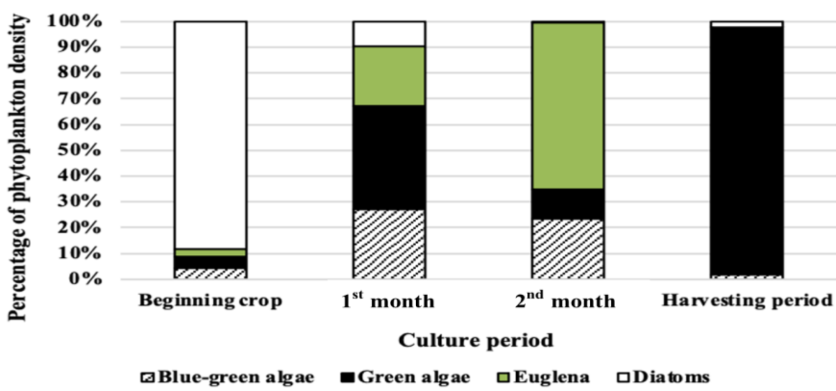

Figure 1. Changes in phytoplankton composition were in study areas

Table 5. Changes in the ecological index of phytoplankton were in each culture period

parameters	Ecological index			
	Beginning crop	**1st month**	**2nd month**	**Harvesting period**
Dominant group	Diatoms	Green algae	Euglenoid	Green algae
Dominant genus	*Cyclotella*	Unidentified genus	*Euglena*	*Scenedesmus*
Average density (cells/L)	1,027.50	3,662.40	7,788.00	153,627.88
Diversity index	0.82	2.04	1.36	0.26
Evenness index	0.12	0.25	0.15	0.02
Dominance index	0.88	0.75	0.85	0.98

Relationship between water quality factors and phytoplankton population in Pacific white shrimp ponds

The correlation coefficiency between the average density of the green algae, euglenoid, diatom and the water quality parameters showed that the total phytoplankton density had a high level of positive correlation (r=0.994) with statistical significance ($p<0.05$) with orthophosphate. Moreover, green algae were also highly related (r=0.990) with orthophosphate ($p<0.05$). It was found that most of the water quality parameters were within the appropriated standard criteria. Although transparency was lower than standard criteria and nitrite was higher than standard criteria in the end of crop, the relationship of the ecological index and water quality parameters also showed that all ecological index had no statistically significant relationship ($p>0.05$) with the water quality parameters in Table 6.

Table 6. Correlation coefficiency (r) between water quality factors and phytoplankton population

Water quality parameters	Correlation coefficient (r)					
	Density of phytoplankton (cells/L)				Ecological index	
	Green algae	Euglenoid	Diatoms	Total density	Diversity	Dominance
Temperature	-0.023 (p=0.977)	0.889 (p=0.111)	-0.248 (p=0.752)	0.010 (p=0.990)	0.288 (p=0.712)	-0.148 (p=0.852)
Transparency	-0.526 (p=0.474)	-0.405 (p=0.595)	-0.318 (p=0.682)	-0.548 (p=0.452)	-0.013 (p=0.987)	-0.132 (p=0.868)
Salinity	0.167 (p=0.833)	-0.637 (p=0.363)	0.377 (p=0.623)	0.145 (p=0.855)	-0.669 (p=0.331)	0.549 (p=0.451)
Dissolved oxygen	0.933 (p=0.067)	-0.052 (p=0.948)	0.824 (p=0.176)	0.943 (p=0.057)	-0.557 (p=0.443)	0.657 (p=0.343)
pH	-0.250 (p=0.750)	0.397 (p=0.603)	-0.419 (p=0.581)	-0.238 (p=0.762)	0.808 (p=0.192)	-0.721 (p=0.279)
Alkalinity	0.301 (p=0.699)	-0.342 (p=0.658)	0.453 (p=0.547)	0.291 (p=0.709)	-0.848 (p=0.152)	0.772 (p=0.228)
Nitrite	0.733 (p=0.267)	0.365 (p=0.635)	0.574 (p=0.426)	0.755 (p=0.245)	-0.482 (p=0.518)	0.609 (p=0.391)
Nitrate	0.316 (p=0.684)	0.745 (p=0.255)	0.099 (p=0.901)	0.348 (p=0.652)	-0.038 (p=0.962)	0.185 (p=0.815)
Total ammonia	0.867 (p=0.133)	0.093 (p=0.907)	0.729 (p=0.271)	0.882 (p=0.118)	-0.469 (p=0.531)	0.586 (p=0.414)
Orthophosphate	0.990* (p=0.010)	-0.237 (p=0.763)	0.942 (p=0.058)	0.994* (p=0.006)	-0.763 (p=0.237)	0.829 (p=0.171)

Remark: * is a statistical significant different ($p<0.05$).

Discussion

Phytoplanktons in Pacific white shrimp ponds of this study were divided into 5 main groups, namely blue-green algae, green algae, euglenoid, diatoms, and dinoflagellate. In accordance with Cremen *et al*. (2007) reported that study of the phytoplankton community composition in the shrimp pond (*Penaeus monodon*) in Philippines. However, if consideration, blue-green algae were the most abundant species (7 species), followed by the green algae group (5 species) and diatoms (4 species), the density of phytoplankton, it was found that there were variations with the culture period. Álvarez-Go ́ngora and Herrera-Silveira (2006) reported that the phytoplankton community structure would change an according to environmental conditions as different times, including nutrients, salinity, and temperature. Consistent with Suriyaphan (2014) reporting that the growth of phytoplankton in aquaculture ponds would change according to the amount of main nutrients in each culture period, especially with the amount of nitrogen and phosphorus groups. At the beginning of the crop, diatoms group was a dominant in terms of volume (87.30% of total phytoplankton). During the first month of the crop, phytoplankton in the groups of blue-green algae, green algae, and euglenoid group had the same density (23.11-40.22%), while the diatoms group was dropped to 9.59%. In the second month of the culture period, euglenoid was the group of phytoplankton that was dominant, about 60.52%. Also, during the harvesting period, green algae group would increase by 95.57% of all phytoplankton density. In the overall culture period, green algae group dominant in quantity (90.20% of all phytoplankton), followed by euglenoid (3.70%) and blue-green algae (3.21%) respectively.

In this study, *Scenedesmus* sp. was the most common phytoplankton in the ponds, with a total density of 147,389.95 cells/liter or 88.73% of the total phytoplankton. This group of phytoplankton was found in both freshwater and brackish. There were more than 600 species of *Scenedesmus* reported phytoplankton grew well in the high nutrient of water sources. Unusually water sources had eutrophication conditions (Phinyo *et al*., 2017). Therefore, the percentage of *Scenedesmus* sp. that was in the ponds (88.73% of all phytoplankton) during the culture period indicated that the nutrient content increased along the culture period and the highest amount being during the harvesting period. A commercial feed in the aquaculture process was the essential source of minerals in aquaculture ponds, especially phosphorus which was the main nutrient to accelerate the growth of phytoplankton from the green algae group (Cremen *et al*., 2007). Commercial feed was added into the intensive aquaculture system caused eutrophication-condition in the pond (Lucas *et al*., 2010) which caused a high increase of the phytoplankton population (Casé *et al*., 2008). Consistent with this study, it was found that the total phytoplankton density had a high level of positive correlation ($r=0.994$) with statistical significance ($p<0.05$) with orthophosphate. Moreover, green algae were also highly related ($r=0.990$) with orthophosphate ($p<0.05$). Considering the results of the water qualities analysis in the ponds, it was found that the most of the water quality parameters were within the appropriate standard criteria. Although transparency was lower than standard criteria and nitrite was higher than standard criteria at the end of crop. It also indicated that the amount of waste accumulated in the ponds would increase with increasing culture period. It was consistent with the density of phytoplankton that increased throughout the culture period. Also, the important water quality parameters as orthophosphate significantly affected the growth of phytoplankton ($p<0.05$). Funge-Smith and Briggs (1998) reported that the most aquaculture ponds, more than 50% of the phosphorus came from feed waste. The phosphorus would remain on sediment more than 80%. Whenever phosphorus in water body decreased, some of the phosphorus in the sediment would be dissolved into the water. Also, phytoplankton could use this nutrient for growth as well.

It is summarized that water quality data along the culture period indicated that the high organic matter accumulated throughout the culture period. Consistent with the total density of phytoplankton increased in the culture period. The farmers must be careful for check the amount of dissolved oxygen at night. If water quality management is not well enough, it might affect the yield in the pond (Lall, 2002; Shoko *et al*., 2014). The last point, *Scenedesmus* sp. was the prominent phytoplankton during the culture period, volume going up to 88.73% of all phytoplankton. The ecological index indicated that it was eutrophication-conditions in the ponds (Phinyo *et al*., 2017) related to the amount of orthophosphate. Therefore, the farmers should remove a feed waste from the ponds and control the amount of feed appropriately because the most of the phosphorus in the pond came from feed waste (Funge-Smith and Briggs, 1998).

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